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EVALUATION OF THE THREE MILE ISLAND ACCIDENT IN THE CONTEXT OF WASH-1400*

by

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The accident at unit 2 of the Three Mile Island nuclear station (TMI-2) on March 28, 1979, occurred after approximately 400 reactor years (RY) of commercial nuclear reactor operation in the US. The purpose of work summarized here was to evaluate the probability statements in the WASH-1400 reactor safety study (RSS)[1] in view of the TMI-2 event and to estimate the likely public impact of TMI-2. The RSS probability estimate for such a release was found to be consistent with the fact that the TMI-2 accident occurred. The expected health effects are consistent with those for a low-level category of radioactivity release as described in the RSS and they are immeasurably small. However, the public perception of the health effects of the release is likely to be much more severe than the estimated health effects.

The nature and severity of the accident coincide with a category of radioactivity release for a pressurized water reactor (PWR) described in RSS as "PWR 8." A PWR-8 release involves damage to the nuclear core but without substantial fuel melting. Radioactive fission products residing in intragranular fuel gaps are assumed to escape into the primary-system coolant, and coolant is assumed to escape the primary system through a small breach. (The primary system involves the nuclear core, the cooling water flowing through the core, and the vessel and piping that contain the water and the core.) Failure of the containment to isolate properly (i.e., prevent the

*Work performed under the auspices of U. S. Nuclear Regulatory Commission.

escape of large amounts of radioactive material) then leads to a release to the environment. The severity of a PWR-8 release is not regarded as significant enough to require evacuation in the vicinity of the reactor. The lowest release category is PWR 9, which involves proper isolation. The higher categories, PWR 1 through PWR 7, involve core meltdown. TMI-2 did involve proper containment isolation. The radio-iodine release was consistent with category PWR 9. Severe fuel damage, however, caused a significant noble gas (radio-xenon) escape consistent with core melt categories. The combined effects of the low iodine and high noble gas releases are consistent with category PWR 8.

To compare the occurrence after 400 RY to the predictions of the RSS,[1] a series of questions must be considered. These involve various levels of detail in describing the accident. First, what was the probability of an accident in either a PWR or BWR (boiling water reactor)? Then, what was the chance that an accident would have occurred in a PWR instead of a BWR? Finally, what was the chance that the PWR accident would have resulted in the level of damage and public radiation exposure realized at TMI-2 instead of more severe consequences arising from core melt? These questions are addressed in following paragraphs.

The RSS's best estimate of the probability of an accident involving reactor core damage and radioactivity release is one in 2 000 yr per reactor for PWRs and one in 7 750 yr per reactor for BWRs. This suggests a 13% chance (approximately 1 part in 8) of having realized at least one such release in the US by March 28, 1979, after approximately 223 RY in PWRs and 187 RY in BWRs. Probability estimates normally are not rejected in statistical analyses until the probability of the observed event(s) is lower than 1 part in 20 (i.e., "95% confidence level" in hypothesis testing). Thus, the fact that an accident involving core damage and radioactivity release occurred is consistent with RSS probability estimates.

The probability that such an accident would have occurred in a PWR instead of a BWR is about 4 parts in 5. This is due to the higher estimated probability of accidents in PWRs by nearly a factor of 4, and the 35% more reactor years of operation in PWRs. Thus, the occurrence of an accident in a PWR was more likely.

The nine categories of radioactivity release for PWR accidents have different relative probabilities of occurrence, with the less severe releases having the higher probabilities. The probability of the PWR-8 catagory release instead of any other is 8%, or about 1 part in 12. This is the second most likely category. (The most likely outcome, a PWR-9 release, has a probability of 80%.) The occurrence of a PWR-8 category release is consistent with the RSS probabilities.

While the occurrence of TMI-2 is consistent with RSS probabilities, it should be noted that the data can be used to support other probability statements as well. For example, the fact that an accident has occurred, releasing radioactivity and damaging the nuclear core after 400 RY, indicates that the probability of an accident could be as high as 1 in 130 per reactor (as compared to the RSS estimates of 1 in 2 000 for PWRs and 1 in 7750 for BWRs). If the probability were higher than this,it would have been unlikely (i.e., less than a 5% chance) to have had only one accident in 400 RY. However, if the probability of an accident were lower than 1 in 7 800 yr per reactor, it would have been unlikely to have had only one accident in 400 RY. Thus, the data support (with 90% statistical confidence) accident probabilities in the range 1 in 130 to 1 in 7 800 per RY. Because existing data on reactor accidents are limited to one event, uncertainty is wide in probability statements made on the basis of the data. In these examples no generic distinction has been made between BWR and PWR probabilities, because the limited data indicate that the probabilities are not necessarily different. The best-estimate probabilities and the conservative probabilities (i.e., 10 times higher than the best estimate) from the RSS lie in this range.

The best estimate of population exposure to radiation is 920 rem for PWR-8 releases. This number is related to expected increases in the incidence of cancer and genetic effects in the population, because the exposure is well below acute illness or fatality limits. The maximum value for a PWR-8 release is listed in the RSS as 15 000 rem (total population dose). The cancer rate from low-level radiation is estimated to be 100 incidents per 1 000 000-rem population exposure. (The rate for genetic effects is conservatively assumed in the RSS to be the same as that for cancer.) This assumes that risk of radiation-induced cancer or genetic effects is directly proportional to radiation dose. Hence the RSS average cancer incidents range from the best estimate of 0.09 to the maximum 1.5. This is equivalent to a probability ranging from a best estimate of 10% to a maximum of 80% of one or more incidents of cancer. The same results apply to genetic effects.

Indications are that the TMI-2 release resulted in about a 3 500-rem population exposure. The recent National Academy of Sciences (NAS) estimate for cancer rate is one per 5 000 rem,[2] which could be as much as fivefold high or low, and which is twice as high as the RSS estimate. Given the NAS rate, 7 000 of the 360 000 annual cancer deaths in the US are attributable to background, low-level radiation sources (for example, atmospheric radon, cosmic rays, medical uses of radiation, natural radio-potassium in the human body). Thus, the average number of cancer incidents from TMI 2 is roughly 3 500/5 000, or 0.7. This is equivalent to a 50% chance of zero incidents, a 35% chance of one, a 12% chance of two, and a 3% chance of three or more.

The societal impact can be evaluated by estimating the effect on life expectancy in the US from low-level radiation exposure from reactor accidents. Based on the estimated health affects of TMI-2, the life expectancy in the US would be decreased less than 2 h if one TMI-2-type accident occurred every week. Further, the rate of genetic effects would increase less than 0.1%.

The perceived impact on the public may be greater than the estimated health effects warrant because a single incident of a radiation-induced health effect is usually not attributable to a specific source (TMI-2, cosmic radiation, atmospheric radon, etc.). The normal pre-accident cancer death rate among the approximately 2 000 000 persons living in the vicinity of TMI-2 is about eight per day. Because many cancers are curable, many more than eight people per day discover they have cancer. It is likely that the public will attribute many of these to the reactor accident. The normal rate of genetic effects (deformities and genetic-related diseases) for the same population is 100 000 per generation.[1] Many of these may be attributed to the accident, although the increased rate of occurrence of genetic effects from the accident is about the same as that of cancer.

REFERENCES

1. "Reactor Safety Study: An Assessment of Accident Risks in US Commercial Nuclear Power Plants," US Atomic Energy Commission report WASH 1400 (October 1975).

2. "Risks Associated with Nuclear Power: A Critical Review of the Literature," Committee on Sciences and Public Policy of the National Academy of Sciences report, advance copy (to be published).